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*Published in:*  
Advanced Solid-State Lasers Congress Technical Digest

*Link to article, DOI:*  
[10.1364/ASSL.2013.JTh2A.23](https://doi.org/10.1364/ASSL.2013.JTh2A.23)

*Publication date:*  
2013

*Document Version*  
Publisher's PDF, also known as Version of record

[Link back to DTU Orbit](#)

*Citation (APA):*  
Høgstedt, L., Tidemand-Lichtenberg, P., & Pedersen, C. (2013). Direct Seeded Single Frequency mid-IR OPA all Passive Light Source. In *Advanced Solid-State Lasers Congress Technical Digest* [JTh2A.23] Optical Society of America. <https://doi.org/10.1364/ASSL.2013.JTh2A.23>

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# Direct seeded single frequency mid-IR OPA all passive light source

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**Abstract:** We present a two stage pulsed mid-infrared light source based on non-linear downconversion of light. The light source is single frequency, tunable, all passive, single moded and build with standard optical components.

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**OCIS codes:** 300.6340, 190.4360, 230.7405

## 1. Introduction

For remote gas spectroscopy measurements as deployed in DIAL systems a single frequency, tunable and pulsed light source is needed. This paper present such a light source in the regime from 2.9  $\mu\text{m}$  to 3.4  $\mu\text{m}$ .

Previous work in this area have presented a light source with two cascaded optical parametric amplifiers (OPA) seeded by a filtered spontaneous parametric fluorescence (SPF) signal from an optical parametric generator [5], a single OPA pumped by a high power Q-switched microchip laser [8] or different implementations of OPO designs [4] and [3].

Our approach is based on direct seeding of an OPA system by a continuous wave single frequency tunable light source. This approach gives us the possibility to control the final output of the light source directly and eliminates the need for synchronization and locking between the units. The output wavelengths are defined from the energy conservation in the difference frequency process in the OPA

$$\frac{1}{\lambda_{\text{signal}}} = \frac{1}{\lambda_{\text{idler}}} - \frac{1}{\lambda_{\text{pump}}} \quad (1)$$

where the signal is the generated pulsed mid-IR field and the CW seed at the same wavelength, the pump is the passive Q-switched laser and the idler is a pulsed field generated from the rest of the energy in the pump photon. The phase match condition of the parametric process is regulated by temperature tuning of periodically poled lithium niobate (PPLN) crystals.

## 2. Experimental setup

The setup consists of four different parts, a tunable external cavity diode laser, an intracavity difference frequency generation module, a guiding and scaling part and finally an OPA-system. The first two parts is described in [2], with a minor change in the cavity design as described in figure 1 and a change of the pumping wavelength for the difference frequency generation laser as suggested in [1]. The new laser design have reduced the footprint of the cavity and increased the overall efficiency. The last two parts of the setup is also displayed in figure 1, where the passive Q-switched laser is described in [7].

The OPA-system is build to have the highest overlap of the beams in the PPLN crystal. This is accomplished by the scaling and guiding optics, and the actual aligning with the infrared seed is done with a double pinhole configuration before inserting the crystal. The crystal is a 40 mm PPLN crystal with 5% Mg doping from Covision Ltd with five different poling periods ranging from 29.52  $\mu\text{m}$  to 31.59  $\mu\text{m}$ , where 30.49  $\mu\text{m}$  is used for the specific measurements presented here.

Generally the modular and independent design of the subsystems eases the optimization of the light source as each part can be optimized independently.

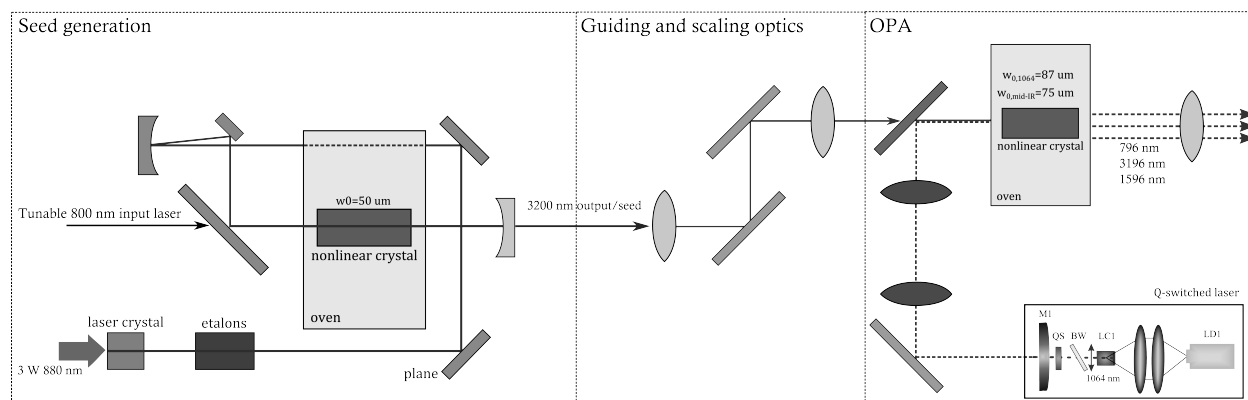


Fig. 1. Experimental setup showing the seed generation to the left, the OPA setup to the right and the guiding and scaling optics in between.

### 3. Results

To characterize the light source we mainly used a thermal power meter and an optical spectrum analyser (Ando AQ6315e). Some important system values are listed in table 1 and a range of spectra are given in figure 2.

Without the seed turned on the OPA emits a broad range of SPF as seen in figure 2 b). When the seed is turned on the signal collapse into a single or few spectral modes, defined by the spectrum of the OPA pump and the seed. This is supported by similar results obtained in [6]. It is a result of adjusting the phase match to the seed where all the energy is transferred to the matched wavelengths. This result in a measurement of a 15 dB larger peak power located in the seed wavelengths only as displayed in part a) compared to the unseeded SPF level in b). Part c) and d) shows two examples of how the spectrum looks when the phase match is not fully satisfied. This combination of the SPF spectrum and the OPA signal peak is an efficient way of fine tuning the phase match condition and correct for the discrepancy in the Sellmeier equations or variations in the poling periods.

Part e) show how the signal looks when the etalons is removed from the seed generating cavity in figure 1, here the spectrum is the convolution of the Q-switched pump spectrum in figure f) and the spectrum from the seed with three or four different peaks. Comparing a) and e) show how the mode filtering of the seed signal is directly correlated with the output from the OPA. The reason a) is not completely single frequency is explained by the pump spectrum in f), that indicates a double peak. We chose to seed directly at the desired wavelength to avoid the convolution of the pump spectrum onto the mid-IR signal. It was not possible to measure the mid-IR signal with the OSA, but measuring the idler strongly indicates the relation between the seed and the output spectrum. Table 1 displays an example of measured values of the seed and the output. This show that the SPF itself has a high output power, but it is important to notice that all this power is collapsed to the signal when the seed is turned on. The peak power of the output signal is calculated to more than 600 W. Currently we work to optimize the seed power to its full potential and find a way of confirming the spectral content and pulse shape of the signal directly.

Table 1. Measured key system values

Average power @ 3197 nm	12 mW
Seed power	4 mW
Output pulse FWHM	7 ns
SPF Output	6 mW
Repetition rate	5 KHz
OPA average pump power	300 mW

### 4. Conclusion

We have demonstrated a tunable, single frequency mid-IR pulsed light source build of all passive components. We show how the SPF spectrum collapse into a single peak when guiding the mid-IR seed to the OPA and that the laser

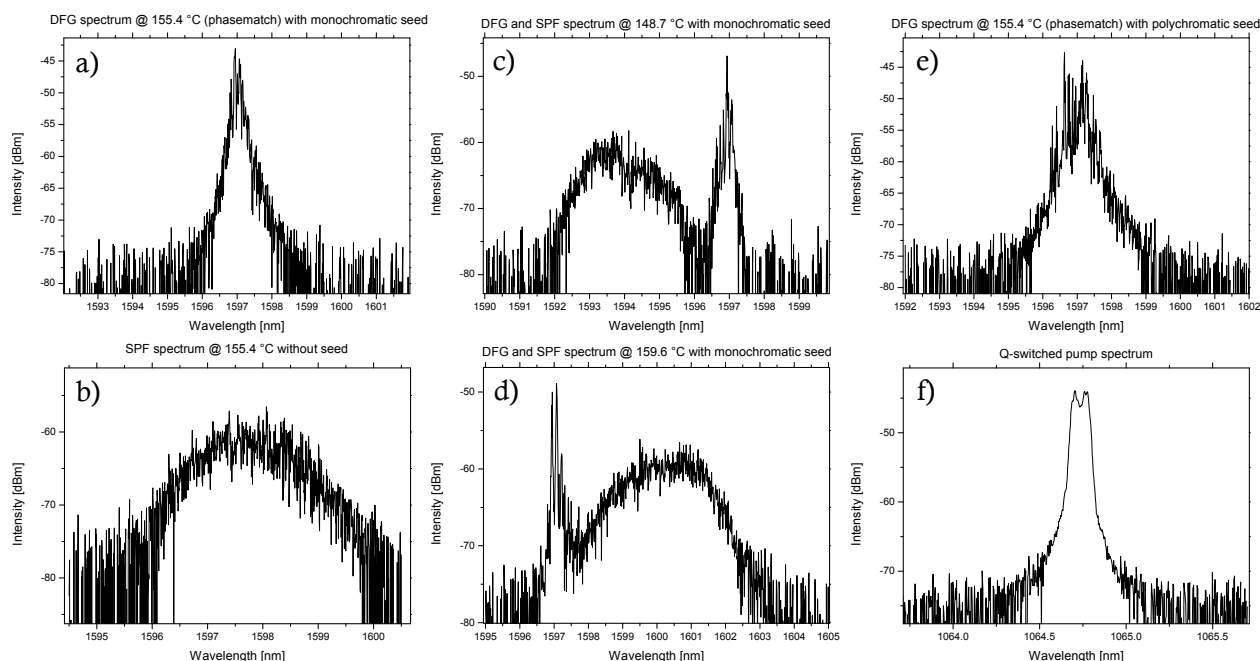


Fig. 2. Measurement data for the pulsed idler signal. a) is the output spectrum with single frequency seed signal on and b) without the seed. c) and d) is two examples of the spectrum when the seed is tuned away from the optimal phase match condition. e) is the spectrum in case of a multiline spectral seed and f) is the spectrum of the OPA pump.

currently is capable of producing more than 600 W of peak power. It is our believe that this light source will be well suited in a DIAL setup for remote gas detection.

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